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IS 7569 (1987): Cast acrylic sheets for use in luminaires  
[ETD 24: Illumination Engineering and Luminaries]

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IS : 7569 - 1987

*Indian Standard*  
SPECIFICATION FOR  
CAST ACRYLIC SHEETS FOR  
USE IN LUMINAIRES  
*( Second Revision )*

UDC 678.744.32-41 : 628.952.5

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BUREAU OF INDIAN STANDARDS  
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG  
NEW DELHI 110002

*Indian Standard*

SPECIFICATION FOR  
CAST ACRYLIC SHEETS FOR  
USE IN LUMINAIRES

*( Second Revision )*

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*Indian Standard*

**SPECIFICATION FOR  
CAST ACRYLIC SHEETS FOR  
USE IN LUMINAIRES**

*( Second Revision )*

**O. F O R E W O R D**

**0.1** This Indian Standard ( Second Revision ) was adopted by the Bureau of Indian Standards on 25 May 1987, after the draft finalized by the Illuminating Engineering and Luminaires Sectional Committee had been approved by the Electrotechnical Division Council.

**0.2** Acrylic sheets are being widely used in various types of luminaires, both as light control and as protective covers for lamps and reflectors. Need had been felt to collect and present data about the characteristics of the material in a manner which would enable luminaire manufacturers to specify accurately those properties of the material which would satisfy their specific requirements.

**0.3** This standard was first published in 1975 and was subsequently revised in 1981. Second revision of this standard has been undertaken to further update some of the requirements and test methods for the sheets. In this revision, a new test relating to the measurement of residual monomer has been added.

**0.4** In preparing this standard extensive assistance has been derived from the specifications published by the American Society for Testing and Materials, USA. The method for the measurement of stability towards yellowing, haze and luminous transmittance, in particular, are based on the following ASTM Standards:

ASTM D-1003 ( 1977 ) Test Method for Haze and Luminous Transmittance of Transparent Plastics

ASTM D-1925 ( 1977 ) Test Method for Yellowness Index of Plastics

**0.5** For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960\*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

\*Rules for rounding off numerical values ( revised ).

## 1. SCOPE

**1.1** This standard covers the mechanical, thermal, optical and physical requirements of cast acrylic sheets used in luminaire.

## 2. TERMINOLOGY

**2.0** For the purpose of this standard, the following definitions shall apply.

**2.1 Cast Acrylic Sheets** — Thermoplastic sheets formed by polymerization of methyl methacrylate monomer by casting process.

**2.2 Haze** — The haze of a specimen is that percentage of transmitted light which in passing through the specimen deviates from the incident beam by forward scattering. For the purpose of this standard, only light flux deviating more than  $2.5^\circ$  on the average is considered as haze.

**2.3 Luminous Transmittance** — The ratio of transmitted to incident light ( sodium D-line ).

**2.4 Diffusion Factor ( of a Diffusing Surface by Reflection and/or by Transmission )** — Ratio of the mean of the values of luminance measured at  $20^\circ$  and  $70^\circ$  to the luminance measured at  $5^\circ$  from the normal, when the surface considered is illuminated normally.

NOTE 1 — The diffusion factor is intended to give an indication of the special distribution of the diffused flux. It is equal to 1 for every uniform diffuser, whatever the value of the diffuse reflectance.

NOTE 2 — This way of defining the diffusion factory can only be applied to materials for which the indicatrix of diffusion does not differ appreciably from that of ordinary depolished and opal glasses.

**2.5 Translucent** — Transmitting light diffusely, but not permitting a clear view of objects beyond the specimen and not in contact with it.

**2.6 Transparency** — The degree of regular transmission, that is the property of a material which enables objects to be seen clearly through a sheet.

**2.7 Yellowness** — Deviation in chroma from whiteness or a water whiteness in the dominant wave length range from 570 to 580 Nm.

**2.8 Yellowness Index (  $YI$  )** — The magnitude of yellowness relative to magnesium oxide for CIE Source C. Yellowness index is expressed as follows:

$$YI = [ 100 ( 1.28 X_{CIE} - 1.06 Z_{CIE} ) ] / Y_{CIE}$$

where

$X_{CIE}$ ,  $Y_{CIE}$  and  $Z_{CIE}$  = tristimulus values ( Note 1 ) of the specimen relative to Source C.

NOTE 1 — By this test method, positive (+) yellowness index describes the presence and magnitude of yellowness; specimen with a negative (-) yellowness index will appear bluish.

**2.9 Change in Yellowness Index ( $\Delta YI$ )** — The difference between an initial value,  $YI_0$ , and  $YI$  determined after a prescribed treatment of the plastic.

$$\Delta YI = YI - YI_0$$

NOTE — By this calculation positive (+)  $\Delta YI$  indicates increased yellowness and negative (-)  $\Delta YI$  indicates decreased yellowness or increased blueness.

### 3. DIMENSIONS

**3.1** The preferred values for the dimensions after trimming for the supply of cast acrylic sheets shall be as follows:

- 765 × 610 mm
- 1 220 × 915 mm
- 1 220 × 1 525 mm
- 1 220 × 1 830 mm
- 1 375 × 915 mm
- 1 830 × 915 mm
- 2 170 × 1 050 mm

**3.1.1** The tolerance for the dimensions shall be  $^{+5}_{-0}$  mm.

NOTE — Above are the dimensions of sheets after trimming. Sheets can also be supplied with gasket as per mutual agreement between the supplier and the purchaser. In case of sheets with gaskets the dimensions should be approx 25 mm plus both in length and width than the trimmed dimensions.

**3.2 Thickness** — The preferred thicknesses for the acrylic sheets shall be as follows:

- 2·0 ± 0·4 mm
- 2·5 ± 0·4 mm
- 3·0 ± 0·5 mm
- 4·0 ± 0·5 mm
- 5·0 ± 0·6 mm
- 6·0 ± 0·7 mm

NOTE 1 — The tolerances given above are for the batch, that is in a batch the sheets can have a minimum and maximum thickness as specified above. However, the tolerance on the thickness of individual sheets shall be only half of those specified for the batch.

NOTE 2 — The sheets may also be supplied in sizes other than those mentioned in this clause as per the mutual agreement between the supplier and the purchaser.

#### **4. MARKING**

**4.1** Every sheet shall be marked with the following:

- a) Name or trade-mark of the manufacturer; and
- b) Dimension indicating length, width and thickness of the sheets.

**4.1.1** The sheets may also be marked with the Standard Mark.

**NOTE** — The use of the Standard Mark is governed by the provisions of the Bureau of Indian Standards Act, 1986 and the Rules and Regulations made thereunder. The Standard Mark on products covered by an Indian Standard conveys the assurance that they have been produced to comply with the requirements of that standard under a well-defined system of inspection, testing and quality control which is devised and supervised by BIS and operated by the producer. Standard marked products are also continuously checked by BIS for conformity to that standard as a further safeguard. Details of conditions under which a licence for the use of the Standard Mark may be granted to manufacturers or producers, may be obtained from the Bureau of Indian Standards.

#### **5. TESTS**

##### **5.1 Classification of Tests**

**5.1.1 Type Tests** — The following shall constitute type tests:

- a) Visual examination (*see 5.2*);
- b) Checking up of dimensions (*see 5.3*)
- c) Specific gravity (*see 5.4*);
- d) Tensile strength and elongation (*see 5.5*);
- e) Impact strength (*see 5.6*);
- f) Water absorption (*see 5.7*);
- g) Burning rate (*see 5.8*);
- h) Effect of heat on rigidity (*see 5.9*);
- j) Refractive index (*see 5.10*);
- k) Stability towards yellowing (*see 5.11*);
- m) Haze and luminous transmittance (*see 5.12*);
- n) Diffusion factory and uniformity of diffusion (*see 5.13*); and
- p) Residual monomer test (*see 5.14*).

**5.1.1.1** For the purpose of carrying out type tests, 5 full size sheets shall be taken and subjected to the tests given in **5.2** and **5.3**. For other tests given in **5.4** to **5.14**, 2 sheets shall be offered for inspection and samples of required dimensions shall be prepared out of them. Samples obtained from the 2 sheets shall be kept separately. Tests shall be carried out from the samples made from any one of the sheets. In case of failure, samples from the other sheet shall be used for repeat tests.

**5.1.1.2 Criteria** — The samples shall be rejected if:

- any of the full size sheet samples fail to conform to the requirements of 5.2 and 5.3, and/or;
- any of the samples made out of the second lot of acrylic sheets fail to conform to the requirements given in 5.4 to 5.14.

**5.1.1.3 Ambient conditions** — The tests given in 5.4 to 5.14 shall be conducted at an ambient temperature of  $27 \pm 2^\circ\text{C}$  and  $65 \pm 5$  percent relative humidity, unless otherwise specified in the particular testing method.

**5.1.2 Acceptance Tests** — The following shall constitute acceptance tests:

- Visual examination ( see 5.2 ); and
- Checking up of dimensions ( see 5.3 ).

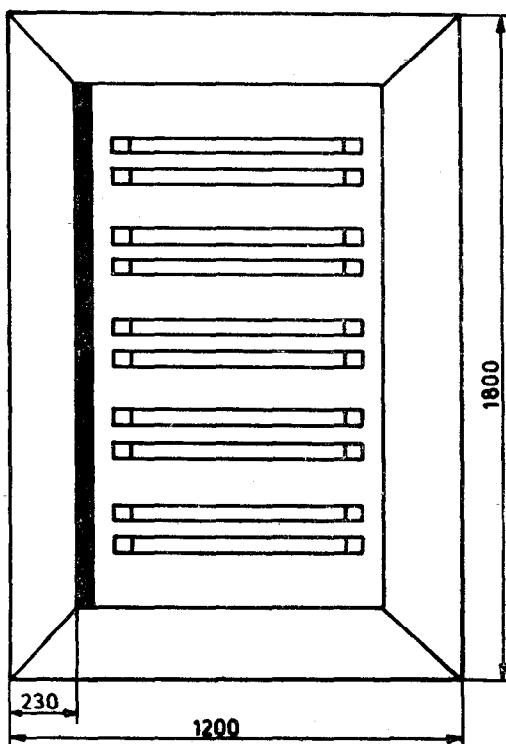
**5.1.3 Routine Tests** — The following tests shall constitute routine tests and shall be carried out on each sheet;

- Visual examination ( see 5.2 ); and
- Checking up of dimensions ( see 5.3 ).

**5.2 Visual Examination** — The sheets shall be visually examined as given in 5.2.1 for scratch, air bubbles, foreign material or any other marks except such special marks which have been specified by the purchaser.

**5.2.1** A colourless ( transparent ) acrylic sheet with alternate black and white lines, approximately 125 mm wide shall be mounted with its lines being vertical. The sheet shall be of such a size that it is able to form a complete background for the largest sample sheet to be inspected. The specimen shall be visually examined by keeping the sheets in front of a vertical illuminator which shall be constructed out of a wooden box as per the details given in Fig. 1. The tube lights are fitted vertically at equidistance in such a way that entire box is illuminated uniformly. Inside of the box shall be painted with black colour. The sheet to be inspected shall be held in a vertical plane at a convenient height by a support set at an angle of  $60^\circ$  to the black and white screen. One edge of the sheet shall be in contact with one edge of the screen. The screen shall be observed through the sheet and examined for distortion of the black and white screen. The sample shall then be rotated in a vertical plane through  $180^\circ$  and the specimen again examined for distortion.

**5.3 Checking Up of Dimensions** — Sample sheets shall be examined for length, width and thickness and shall comply with the values specified by the purchaser subject to tolerances specified.



All dimensions in millimetres.

FIG. 1 FLUORESCENT BOX FOR VISUAL EXAMINATION

**5.4 Specific Gravity** — The specific gravity of a sample sheet shall be measured by the procedure given in Appendix A and the values of the specific gravity shall not be less than 1.18 and more than 1.24.

**5.5 Tensile Strength and Elongation** — A test specimen shall be cut from the sheets as per the dimensions shown in Appendix B. The specimen tested in accordance with Appendix B shall show a minimum tensile strength of 56 N/mm<sup>2</sup> (*see also A-7 of IS : 2267-1972\** for test procedure). The elongation at rupture shall not be less than 4.5 percent.

**5.6 Impact Strength** — The test shall be carried out in a suitable impact testing machine using a standardized pendulum type hammer (Izod method) and average impact strength in Joules/metre of width

\*Polystyrene moulding materials (*first revision*).

of the specimen shall be calculated from the test. The impact strength of the sheets shall not be less than 21·6 Joules/metre notch.

**NOTE** — Guidance regarding determination of impact strength by Izod type impact testing machine may be taken from A-6 of IS : 2267-1972\*. The test specimen for impact strength test shall be cut from the sheet as per the dimensions indicated in Fig. 3 of IS : 2267-1972\*

**5.7 Water Absorption** — A test sample, 75 mm long  $\times$  25 mm wide  $\times$  thickness of material, shall be tested in accordance with Appendix C. The water absorption shall not be more than 0·4 percent of the dry weight of the sample after 24 hours' immersion.

**5.8 Burning Rate** — A test sample, 125  $\pm$  5 mm in length  $\times$  12·5  $\pm$  0·2 mm in width  $\times$  the thickness of the sheet, shall be tested according to Appendix D. The sample shall show a burning rate of not more than 40 mm per minute.

**5.9 Effect of Heat on Rigidity** — A test sample 125 mm in length  $\times$  12·5 mm in depth  $\times$  any width from 3 to 13 mm shall be immersed in a bath which can be heated and subjected to fibre stress of 185 N/cm<sup>2</sup>. The specimen shall not show a deflection of 0·25 mm until it reaches a temperature in excess of 85°C when tested in accordance with the method prescribed in Appendix E.

**5.10 Refractive Index** — A test sample made out of colourless transparent sheet and tested according to Appendix F shall show a refractive index not more than 1·5 when tested at 27  $\pm$  2°C with sodium D-line.

### 5.11 Stability Towards Yellowing

**5.11.0** This test shall be carried out by the methods given in **5.11.1**.

**5.11.1 Yellowness Index Method** — This method is intended primarily for determining the degree of yellowness ( or change on degree of yellowness ) under day light illumination of cast acrylic sheets. This method is based upon tristimulus values calculated from data obtained on the hardy GE type spectrophotometer or any other suitable equivalent apparatus.

The magnitude and sign of the yellowness index is calculated from the following equation:

$$YI = [ 100 ( 1·28 X_{CIE} - 1·06 Z_{CIE} ) ] / Y_{CIE}$$

**5.11.1.1 Change in yellowness index** — The magnitude and direction of change in yellowness index is calculated from the following equation:

$$\Delta YI = YI - YIo$$

where

$X_{CIE}$ ,  $Y_{CIE}$  and  $Z_{CIE}$  = tristimulus values of the specimen relative to source C.

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\*Polystyrene moulding materials (*first revision*).

**5.11.1.2** The guidance regarding derivation of equations for calculation of yellowness index from photoelectric tristimulus colorimeter measurements is given in Appendix G.

**5.12 Haze and Luminous Transmittance** — The test sample shall be tested in accordance with Appendix H. In the case of transparent sheets, the sample shall show a minimum transmittance of 91 percent and the haze percentage shall not be more than 3.

**5.12.1** The test report shall include the following data:

- a) total luminous transmittance,  $T_t$ ;
- b) diffuse luminous transmittance,  $T_d$ ; and
- c) percentage haze.

NOTE — The translucent material, the value of luminous transmittance shall be agreed between the purchaser and the supplier.

**5.13 Diffusion Factor and Uniformity of Diffusion ( for Translucent Sheets only )**

**5.13.1 Diffusion Factor**

**5.13.1.1** It is the ratio of the mean of the values of luminance measured at  $20^\circ$  and  $70^\circ$  to the luminance measured at  $5^\circ$  from the normal, when the surface considered is illuminated normally.

**5.13.1.2** The specimen being measured is illuminated on one face by a beam of light normal to the surface. The luminance measurements shall be obtained by using a photometer at  $70^\circ$ ,  $20^\circ$  and  $5^\circ$  to the normal to the specimen. The diffusion factor then shall be calculated as:

$$\text{Diffusion factor} = \frac{L_{20} + L_{70}}{2 L_5}$$

where

$L_5$ ,  $L_{20}$  and  $L_{70}$  are the luminance values of the surface when viewed at  $5^\circ$ ,  $20^\circ$  and  $70^\circ$  to the normal.

**5.13.2 Uniformity of Diffusion** — This test is applicable only for sheets having diffusion factors between 0.85 and 0.9, when measured as in 5.13.1. For this test, a rectangular box containing one 20 W tubular fluorescent lamp shall be used. The inside of the box shall be painted matt black. One long side of the box shall be opened and it shall contain a slot, so that acrylic sheet of  $610 \times 100 \times 3$  mm may be placed there to cover the lamp completely and the sheet remains 70 mm away

from the lamp surface. One test sheet shall be placed in this box and viewed from outside while the lamp is burning. The test sheet shall appear to be uniformly bright.

**NOTE 1** — The testing facilities for carrying out these tests are not readily available in the country. Till such time the testing facilities are created in the country, these tests should be done only after mutual agreement between the manufacturer and the buyer.

**NOTE 2** — The test procedure for sheets having different values of diffusion factor is under consideration.

**5.14 Residual Monomer Test** — The test shall be carried out in accordance with Appendix J. The residual monomer should not exceed by more than 2 percent by weight.

## A P P E N D I X A

( Clause 5.4 )

### METHOD OF MEASUREMENT OF SPECIFIC GRAVITY

#### A-1. APPARATUS

**A-1.1** The apparatus required in these tests are:

- a) *Analytical Balance* — A balance with a precision within 0.1 mg, accuracy within 0.05 percent relative ( that is 0.05 percent of the weight of the specimen in air ), and equipped with a stationary support for the immersion vessel above the balance pan ( pan straddle ).
- b) *Wire* — A corrosion-resistance wire for suspending the specimen.
- c) *Sinker* — A sinker for use with specimens of plastics having specific gravities less than 1.
- d) *Immersion Vessel* — A beaker or other wide-mouthed vessel for holding the water and immersed specimen.
- e) *Thermometer* — A thermometer with an accuracy of  $\pm 1^{\circ}\text{C}$ .

#### A-2. PROCEDURE

**A-2.1** The test specimen shall be a single piece of the material under test of any size and shape that can conveniently be prepared and tested, provided that its volume shall not be less than 1 cm<sup>3</sup> and its surface and edges shall be made smooth. The thickness of the specimen shall be at least 1 mm for each 1 g of weight. A specimen weighing 1 g to 5 g usually will be found convenient, but specimens up to approximately 50 g may be used. Care shall be taken in cutting specimens to avoid changes in density resulting from compressive stresses or frictional heating.

**A-2.2** Weigh the specimen in air to the nearest 0·1 mg or 0·05 percent relative, whichever is greater and record it as 'a'.

**A-2.3** Attach to the balance a piece of fine wire sufficiently long to reach from the hook above the pan to the support for the immersion vessel. Attach the specimen to the wire, such that it is suspended about 25 mm above the vessel support.

**A-2.4** Mount the immersion vessel on the support and completely immerse the suspended specimen ( and sinkers, if used ) in water at a temperature of  $27 \pm 2^{\circ}\text{C}$ . The vessel shall not touch the wire or specimen. Remove any bubbles adhering to the specimen, wire or sinker, paying particular attention to the holes in the specimen and sinker. Weigh the suspended specimen to the required precision. Record this mass as 'b', the weight of the specimen, sinker, if used, partially immersed wire in liquid. Unless otherwise specified, weigh rapidly in order to minimize absorption of water by the specimen.

**A-2.5** Weigh the wire ( and sinker, if used ) in water with immersion to the same depth as used in the previous step. Record this mass as 'w' ( mass of the wire in liquid ).

### **A-3. CALCULATIONS**

**A-3.1** Calculate the specific gravity of the sheet as follows:

$$\text{Specific gravity} = \frac{a}{a + w - b}$$

where

$a$  = apparent mass of specimen, without wire or sinker, in air;

$b$  = apparent mass of specimen ( and of sinker, if used ) completely immersed and of the wire partially immersed in water; and

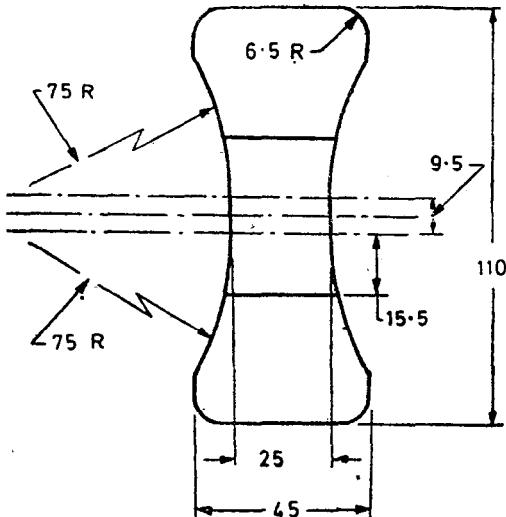
$w$  = apparent mass of totally immersed wire ( and of sinker, if used ) and of partially immersed wire in water.

**A P P E N D I X B**

( Clause 5.5 )

**TEST FOR TENSILE STRENGTH AND ELONGATION****B-1. PREPARATION OF TEST SPECIMEN**

**B-1.1** The test specimen shall be cut from the sheet of the following dimensions:



All dimensions in millimetres.

**NOTE** — All surfaces of the specimen shall be free from visible flaws, scratches or imperfections.

**B-2. CONDITIONING**

**B-2.1** Keep the test specimens in a desiccator over anhydrous calcium chloride for at least 16 hours before testing.

**B-3. PROCEDURE**

**B-3.1** Allow a definite time interval, not exceeding 60 minutes, to elapse between removal of the specimen from the desiccator and application of load. Use any standard testing machine and hold the specimen firmly in grips as shown in Fig. 2.

Increase the load evenly, so that the specimen breaks within 0.5 to 1.5 minutes from the start of the load. Record the maximum load carried by the specimen during the test.

**B-4. CALCULATION**

**B-4.1** Express the tensile strength of each specimen in N/mm<sup>2</sup> of the original minimum cross-sectional area calculated from the measured dimensions of the specimen.

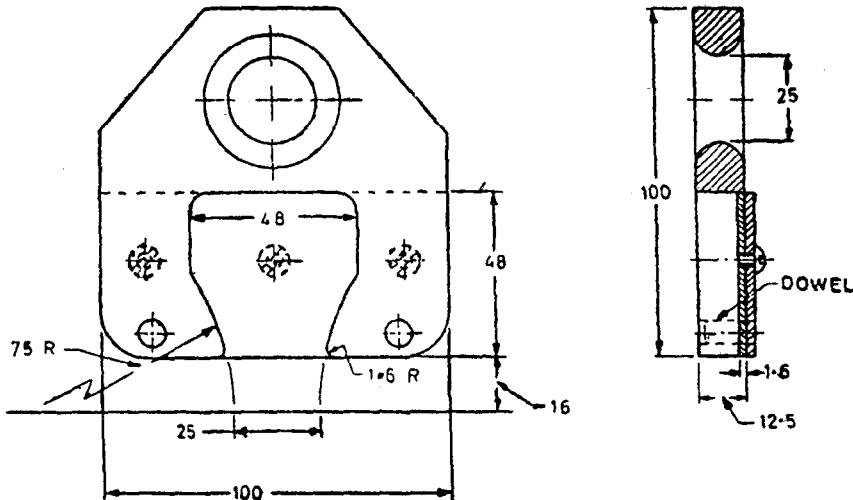


FIG. 2 HOLDER FOR TENSILE TEST SPECIMEN

**A P P E N D I X C**

(Clause 5.7)

**TEST FOR WATER ABSORPTION****C-1. PROCEDURE**

**C-1.1** Condition the specimens as in **B-2**. Measure the thickness to the nearest 0.03 mm, weigh to the nearest milligram and immerse for a period of  $24 \pm 1$  hours in distilled water (*see IS : 1070-1977\**) at  $27 \pm 2^\circ\text{C}$ . On removal from water, wipe dry the exposed surface with blotting paper or clean cloth. Reweigh the specimen to the nearest milligram and complete the weighing within 2 minutes of the removal of the specimen from water. Record the increase in mass in milligrams.

**C-2. CALCULATION AND REPORT**

**C-2.1** When the test has been carried out at an immersion temperature higher than  $20^\circ\text{C}$ , calculate the equivalent water absorption at  $20^\circ\text{C}$  by applying the correction factor given in Fig. 3. Report this as the water absorption for the mean thickness of the specimen under test at  $20^\circ\text{C}$ .

NOTE — Report the temperature of the water at which test was carried out.

\*Specification for water for general laboratory use (*second revision*).

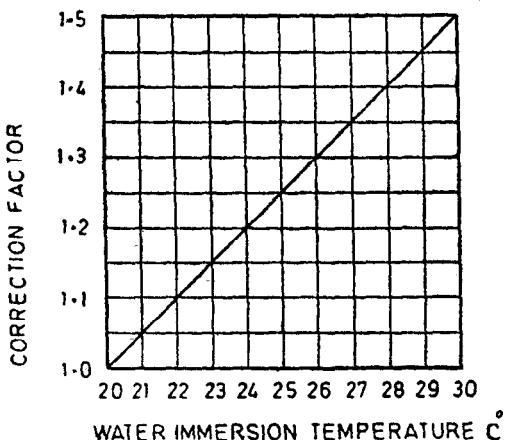


FIG. 3 CORRECTION FACTOR FOR INTERPRETATION OF VALUES OF WATER ABSORPTION

## A P P E N D I X D

( Clause 5.8 )

### TEST FOR BURNING RATE

#### D-1. APPARATUS

**D-1.1 Test Chamber** — A laboratory hood, totally enclosed, with a heat-resistant glass window for observing the test. The exhaust fan is turned off during the test and turned on immediately following the test in order to remove products of combustion which may be toxic when testing some materials.

#### D-2. PROCEDURE

**D-2.1** Clamp one end of the specimen to a support with its longitudinal axis horizontal and its transverse axis inclined at 45° to the horizontal. Under the test specimen clamp a piece of 20 mesh Bunsen burner gauze, about 10 cm square, in a horizontal position 10 mm below the edge of the specimen, and with about 13 mm of the specimen extending beyond the edge of the gauze. Any material remaining on the screen from the previous test must be burned off or a new screen used for each test. A pan of water shall be placed on the floor of the hood in position to catch any burning particles which may drop during the test.

**D-2.2** Adjust a standard 1-cm diameter Bunsen burner with airports open to produce a blue flame approximately 25 mm high. For each attempt to ignite the specimen, place the burner so that the tip of the

flame contacts the end of the test specimen. At the end of 30 seconds, remove the flame and place it at least 450 mm from the specimen to reduce the effects of draft in the hood while the specimen is allowed to burn. In case the plastic does not continue to burn after the first ignition, place the burner in contact with the free end for a second period of 30 seconds immediately after the specimen ceases to burn. Extinguish the burner flame after the second application and close the hood door for the remainder of the test.

**D-2.3** Measure the extent of burning along the lower edge of the test specimen. If the specimen does not ignite on two attempts, the result is judged to be 'nonburning by this test'. If the specimen continues to burn after the first or second ignition, start the stop watch when the flame along the lower edge reaches the mark 25 mm from the free end, and measure the time  $t$  (in seconds) until the flame reaches the mark 100 mm from the free end. A specimen that burns to the 100 mm mark is judged to be 'burning by this test', and its burning rate is equal to  $457/t$  cm per minute. If a specimen does not burn to the 100 mm mark after the first or second ignition, it is judged to be 'self-extinguishing by this test', and 100 mm minus the unburned length (in centimetres) from the clamped end, measured along the lower edge, is its 'extent of burning'.

## A P P E N D I X E

( Clause 5.9 )

### TEST FOR EFFECT OF HEAT

#### E-1. APPARATUS

**E-1.1** The apparatus shall be constructed essentially as shown in Fig. 4 and shall consist of the following.

**E-1.1.1 Specimen Supports** — Metal supports for the specimen which shall be 10 cm apart, allowing the load to be applied on the top of the specimen vertically and midway between the supports. The contact edges of the supports and of the piece by which pressure is applied shall be rounded to a radius of 3·2 mm. The vertical members which attach the specimen supports to the upper plate shall be made of a material having the same coefficient of linear thermal expansion as that used for the rod through which the load is applied.

NOTE — Unless these parts have the same coefficient of linear expansion, the differential change in length of these parts introduces an error in the reading of the apparent deformation of the specimen. A test shall be made on each apparatus using a test bar made of material having a low coefficient of expansion. The temperature range to be used shall be covered and a correction factor of 0·013 mm or greater (its algebraic sign shall be noted) shall be applied to each test by adding it algebraically to the reading of apparent deflection of the test specimen.

**E-1.1.2 Immersion Bath** — A suitable liquid heat-transfer medium (*see Note 1*) in which the specimen shall be immersed. It shall be well stirred during the test and shall be provided with a means of raising the temperature at  $2 \pm 0.2^\circ\text{C}/\text{mm}$  (*see Note 2*).

NOTE 1 — A liquid heat-transfer medium shall be chosen which will not effect the rigidity of the specimen. Mineral oil is considered safe from ignition up to  $115^\circ\text{C}$ . Silicon oil may be heated to about  $260^\circ\text{C}$  for short periods of time.

NOTE 2 — The specified heating rate can be conveniently maintained by the use of an electric hot plate or immersion heater, if the current through these units is regulated by a variable transformer or rheostat.

**E-1.1.3 Weights** — A set of weights of suitable sizes shall be used, so that the specimen can be loaded to a fibre stress of  $185 \text{ N/cm}^2 \pm 2.5$  percent for the first part of the test described in E-4.1 and  $46 \text{ N/cm}^2$  percent for the procedure described in E-4.2. The mass of the rod that applies the testing force shall be determined and included as part of the total load. If a dial gauge is used, the force exerted by its spring shall be determined and shall be included as part of the load (*see Notes 1 and 2*). The load shall be calculated as follows:

$$P = \frac{2 Sbd^2}{3l}$$

where

$P$  = load in N;

$S$  = maximum fibre stress in the specimen of  $185 \text{ N/cm}^2$  when tested according to E-4.1, and  $46 \text{ N/cm}^2$  when tested according to E-4.2;

$b$  = width of specimen in cm;

$d$  = depth of specimen in cm; and

$l$  = width of span between supports (10 cm).

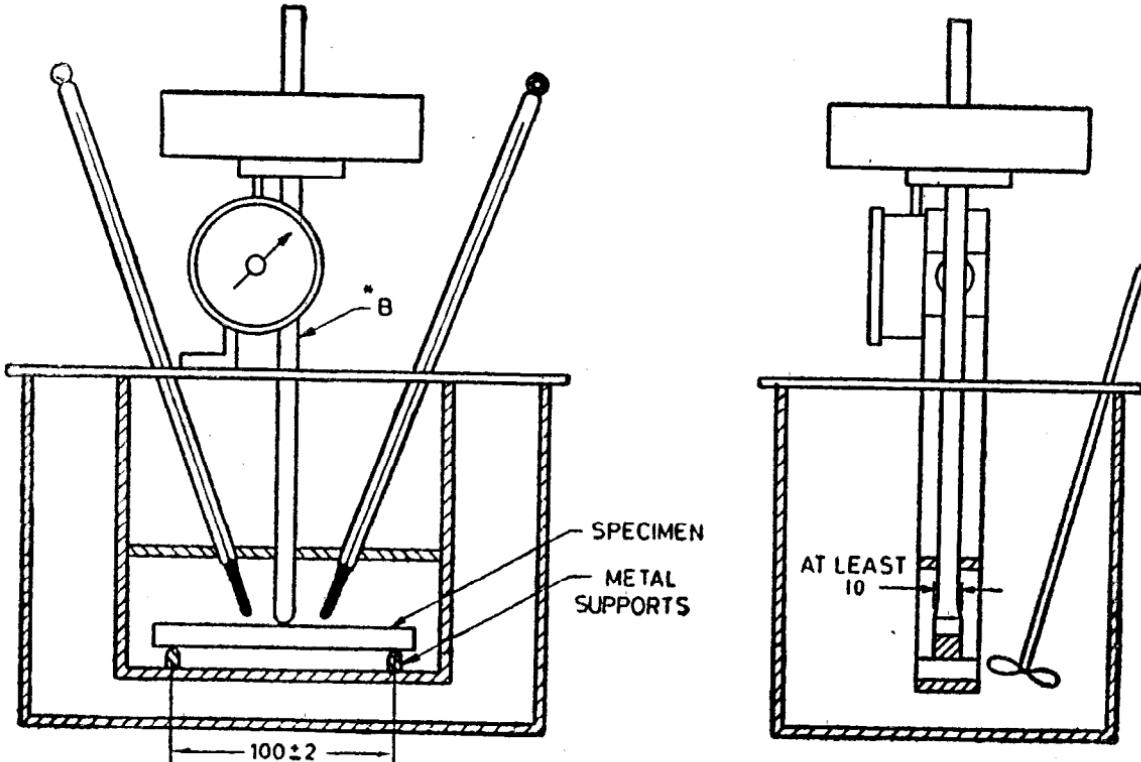
NOTE 1 — In some designs of this apparatus, the force of the dial gauge spring is directed upwards and shall be subtracted from the load, while in other designs this force acts downwards and shall be added to the load.

NOTE 2 — Since the force exerted by the spring in certain dial gauges varies considerably over the stroke, this force shall be measured in that part of the stroke which is to be used.

**E-1.1.4 Thermometer** — The thermometer shall be capable of having a range of  $-20^\circ\text{C}$  to  $+150^\circ\text{C}$ , or its equivalent.

## E-2. PREPARATION OF APPARATUS

**E-2.1** The apparatus shall be arranged so that the deflection of the mid-point of the specimen can be measured on a scale calibrated to  $0.01 \text{ mm}$ . The apparatus may be arranged to shut off the heat automatically and sound an alarm when the specified deflection has been reached. Sufficient heat-transfer liquid shall be used to cover the thermometers to the point specified in their calibration.



\**B* is a metal rod through which load is applied. It is made of material of the same coefficient of linear expansion as that of the vertical members which attach the metal supports to the upper plate. The contact edge shall be rounded to a radius of  $3.0 \pm 0.2$  mm.

All dimensions in millimetres.

**FIG. 4 APPARATUS FOR DETERMINATION OF TEMPERATURE OF DEFLECTION UNDER LOAD**

### **E-3. CONDITIONING**

**E-3.1** The specimens shall be conditioned as detailed in **B-2**.

### **E-4. PROCEDURE**

**E-4.1** Place the test specimen in the apparatus with its 125 mm dimension vertical. In the case of a  $125 \times 125$  cm bar, compression moulded or cut from moulded sheets, place the bar so that the direction of the testing force will be perpendicular to the direction of the moulding pressure. The thermometers shall extend to within 3·2 mm of the specimen, but shall not touch it. The temperature of the bath shall be  $23 \pm 1^\circ\text{C}$  at the start of each test, unless previous tests have shown that for the particular material under test no error is introduced by starting at a higher temperature. Adjust the load so that the fibre stress is  $185 \text{ N/cm}^2 \pm 2.5$  percent, as calculated by the equation given in **E-1.1.3**. Allow the load to act for 5 minutes. Report the temperature at which the bar has deflected 0·25 mm as the deflection temperature at  $185 \text{ N/cm}^2$  fibre stress.

NOTE — The 5 minutes waiting period is provided to compensate partially for the creep exhibited by several materials at room temperature when subjected to the prescribed fibre stress. That part of the creep which occurs in the initial 5 minutes is usually a large fraction of that which occurs in the first 30 minutes.

**E-4.2** The second part of the test shall be conducted exactly as prescribed in **E-4.1**, except that the load is adjusted to produce a fibre stress of  $46 \text{ N/cm}^2 \pm 2.5$  percent, as calculated by the equation given in **E-1.1.3**. Report the temperature at which a deflection of 0·25 mm is reached as the deflection temperature at  $46 \text{ N/cm}^2$  fibre stress.

## **A P P E N D I X F**

( Clause 5.10 )

### **TEST FOR REFRACTIVE INDEX**

#### **F-1. APPARATUS**

**F-1.1** The apparatus for the test shall consist of an Abbe refractometer, a suitable source of white light, and a small quantity of a suitable contacting liquid.

NOTE — Other suitable refractometers can be used with appropriate modification of procedure as described in **F-3.1**.

#### **F-2. TEST SPECIMEN**

**F-2.1** The test specimen shall be of a size such as will conveniently fit on the face of the fixed half of the refractometer prisms. A specimen measuring  $12.5 \times 6$  mm on one face is usually satisfactory.

**F-2.2** The surface to be used in contact with the prism shall be flat and shall have a good polish. A second edge surface, perpendicular to the first and on one end of the specimen, shall be prepared with a fair polish. The polished surfaces shall intersect without a bevelled or rounded edge.

### **F-3. PROCEDURE**

**F-3.1** Remove the hinged illuminating prism from the refractometer, if necessary. Place a source of diffuse light, so that good illumination is obtained along the plane of the surface of contact between the specimen and the refractometer prism. Place a small drop of a suitable contacting liquid on the polished surface of the specimen and then place the specimen in firm contact with the surface of the prism and with the polished edge of the specimen towards the source of light. Determine the index of refraction in the same manner as for liquids. This shall be done by moving the index arm of the refractometer until the field seen through the eyepiece is one-half dark. Adjust the compensator ( Amici prisms ) drum to remove all colour from the field. Adjust the index arm by means of the vernier until the dividing line between the light and dark portions of the field exactly coincides with the intersection of the cross-hairs as seen in the eyepiece. Read the value of the index of refraction for the sodium D-line directly from the instrument. Determine the dispersion by reading the compensator drum and applying this figure, along with the index of refraction, to a chart or table supplied with the instrument.

**Note** — Sodium light from some type of a sodium burner is of use in increasing the accuracy and ease of setting of the refractometer.

## **A P P E N D I X G** *( Clause 5.11.1.2 )*

### **DERIVATION OF EQUATIONS FOR CALCULATION OF YELLOWNESS INDEX FROM PHOTOELECTRIC TRISTIMULUS COLORIMETER MEASUREMENTS**

**G-1.** By the definition given in 2.8, yellowness index has been defined as:

$$YI = [ 100 ( 1.28 X_{CIE} - 1.06 Z_{CIE} ) ] / Y_{CIE}$$

where

$X_{CIE}$ ,  $Y_{CIE}$  and  $Z_{CIE}$  = tristimulus values ( CIE Source C ) obtained by integration from spectrophotometric data as described in 5.11.1.

**G-2.** The equations giving calculated tristimulus values from the filter photometer readings are as follows:

$$X_{\text{CIE}} = 0.7832 A_0 f_x + 0.197 Z_0 f_z$$

$$Y_{\text{CIE}} = 1.0000 Y_0 f_y$$

$$Z_{\text{CIE}} = 1.18103 Z_0 f_z$$

where

$A_0$ ,  $Y_0$  and  $Z_0$  = instrumental filter ( amber, green, and blue reflectance ) values relative to an instrument reference standard, and

$f_x$ ,  $f_y$  and  $f_z$  = ratios of the reflectances of the instrument reference standard to magnesium oxide for each filter.

**G-3.** Substituting these expressions for  $X_{\text{CIE}}$ ,  $Y_{\text{CIE}}$  and  $Z_{\text{CIE}}$  in the equation for yellowness index (**G-1**).

$$\begin{aligned} TI &= \frac{100 [ 1.28 ( 0.7832 A_0 f_x + 0.197 Z_0 f_z ) - 1.06 ( 1.18103 Z_0 f_z ) ]}{1.0000 Y_0 f_y} \\ &= \frac{100 ( 1.002 A_0 f_x + 0.2524 Z_0 f_z - 1.2524 Z_0 f_z )}{Y_0 f_y} \\ &= 100 ( 1.002 A_0 f_x - 0.999 Z_0 f_z ) / Y_0 f_y \end{aligned}$$

**G-4.** Thus, within the precision of the method, for reflectance measurements,

$$TI = 100 ( A_0 f_x - Z_0 f_z ) / Y_0 f_y$$

For transmittance measurements ( $f_x = f_y = f_z = 1$ ), this equation reduces to:

$$TI = 100 ( A_0 - Z_0 ) / Y_0$$

These equations permit calculation of the yellowness index from tristimulus filter colorimeter readings without the labour of calculating approximate tristimulus values.

## A P P E N D I X H

( Clause 5.12 )

### TEST FOR HAZE AND LUMINOUS TRANSMITTANCE

#### H-1. SCOPE

**H-1.1** The method described in this Appendix is intended to measure the light-transmitting properties and from these the light-scattering properties of planer sections of a transparent material.

**H-1.2** The significance of the haze results obtained improves with the avoidance of heterogeneous surfaces and internal defects which can contribute to the diffusion or deviation of light. With this precaution and careful calibration of the apparatus results may be obtained with a precision of  $\pm 0.1$  percent of haze. Differences of this order are rarely detectable visually, in accordance with the definition given, the accuracy of test results obtained by different operators and equipment is of the order of  $\pm 0.3$  percentage haze and, though these results are empirical, they are of value for control purposes and may be related to more fundamental properties useful in research.

#### H-2. APPARATUS

**H-2.1** The hazemeter shall be constructed essentially as shown in Fig. 5 or 6 and shall conform to the requirements in the following paragraph.

**H-2.2** An integrating sphere shall be used to collect transmitted flux; the sphere may be of any diameter so long as the total port area does not exceed 4 percent of the internal reflecting area of the sphere.

**H-2.3** Fig. 5 and 6 indicate possible arrangements of the apparatus. The entrance and exit ports shall be centred on the same great circle of the sphere and there shall be at least  $170^\circ$  of arc between centres. The exit port shall subtend an angle of  $8^\circ$  at the centre of the entrance port.

The axis of the irradiating beam shall pass through the centres of the entrance and exit ports. The photocell or photocells shall be positioned on the sphere  $90 \pm 10^\circ$  from the entrance port. In the pivotable modification of this type ( see Fig. 6 ), designed to sue the interior sphere wall adjacent to the exit port as the reflectance standard, the angle of rotation shall not exceed  $10^\circ$ .

**H-2.4** The specimen shall be illuminated by a substantially unidirectional beam; the maximum angle which any ray of this beam makes with the direction of its axis shall not exceed  $3^\circ$ . This beam shall not be vigneted at either port of the sphere.

**H-2.5** When the specimen is placed immediately against the integrating sphere at the entrance port, the angle between the normal to its surface and the axis of the beam shall not exceed  $8^\circ$ .

**H-2.6** When the beam is unobstructed by a specimen, its cross-section at the exit port shall be approximately circular, sharply defined and concentric within the exit port, leaving an annulus of  $1.3 \pm 0.1$  subtended at the entrance port.

**H-2.7** The surface of the interior of the integrating sphere, baffles and reflectance standards shall be of substantially equal reflectance, matt and highly reflecting throughout the visible wavelengths.

**H-2.8** For some measurements, the standard at the exit port is replaced by a light trap by actual removal of the reflectance standard or by pivoting the sphere (*see* Fig. 6). The light trap shall absorb the beam completely when no specimen is present.

**H-2.9** The radiant flux within the sphere shall be measured by a photo-electric cell, the output measurements of which shall be proportional within one percent to the incident flux over the range of intensity used. Spectral conditions for source and receiver shall be constant throughout the test of each specimen. The design of the instrument shall be such that there shall be no galvanometer deflection when the sphere is dark.

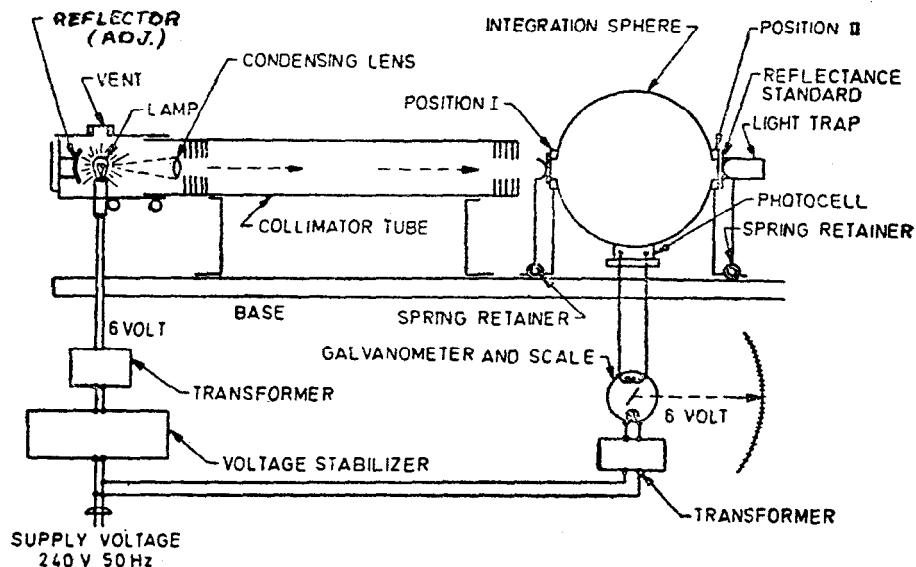
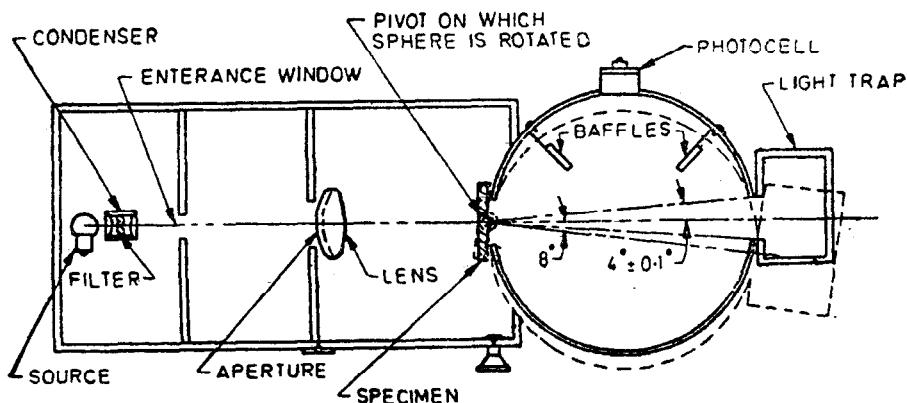


FIG. 5 HAZEMETER



NOTE — Dotted lines show position of sphere for total transmission measurements.

FIG. 6 PIVOTABLE-SPHERE HAZEMETER

### H-3. PROCEDURE

#### H-3.1 Determine the following four readings:

<i>Reading Designation</i>	<i>Specimen in Position</i>	<i>Light Trap in Position</i>	<i>Reflectance in Standard Position</i>	<i>Quantity Represented</i>
$T_1$	no	no	yes	Incident light
$T_2$	yes	no	yes	Total light transmitted by specimen
$T_3$	no	yes	no	Light scattered by instrument
$T_4$	yes	yes	no	Light scattered by instrument and specimen

#### H-3.2 Repeat readings for $T_1$ , $T_2$ , $T_3$ and $T_4$ with additional specified position of the specimen to determine uniformity.

### H-4. CALCULATION

#### H-4.1 Calculate total transmittance, $T_t$ ( see Note ) equal to $T_2/T_1$ .

**H-4.2** Calculate diffuse transmittance,  $T_d$  ( see Note ) as follows:

$$T_d = \frac{T_4 - T_3 \left( \frac{T_2}{T_1} \right)}{T_1}$$

**H-4.3** Calculate percentage haze as follows:

$$\text{Haze, percent} = \frac{T_d}{T_t} \times 100$$

**NOTE** — To obtain luminous transmittance values ( total  $T_t$ ; diffuse  $T_d$  ) by this procedure, a proper source-filter photocell system shall be employed. A Western Type III photocell, with Viscor filter, approximates the response of the standard observer except at the extremes of the visible spectrum. The source may be operated at a colour temperature approximating 2 854 K ( CIE Source A ) by proper selection of voltage. CIE Source C may be achieved with CIE Source A and a filter described by R. Davis and K. S. Gibson, Miscellaneous Publication No. 114, Nat. Bureau Standards, January 1931. An approximation of CIE Source C may be obtained with the lamp operating at 3 100 K plus a Corning Type 5 900 filter of standard thickness.

Commercially produced hazemeters are equipped to provide luminous transmittance measurements using either CIE Source.

To obtain greatest accuracy in luminous transmittance measurements, specially for dark or highly saturated colours, the photometer shall be used as a comparison instrument with a standard of known transmittance similar to that of the specimen.

**H-4.4** The derivation of the formula for haze is as follows:

- a) Total luminous transmittance,  $T_t$  is calculated as follows:

$$T_t = \frac{T_2}{T_1}$$

where

$T_2$  = total light transmitted by the specimen, and

$T_1$  = incident light.

- b) If  $T_3$ , the light scattered by the instrument, is zero, the diffuse luminous transmittance,  $T_d$ , is calculated as follows:

$$T_d = \frac{T_4}{T_1}$$

where

$T_4$  = light scattered by the instrument and specimen.

- c) If  $T_2$  is greater than zero due to light scattered by the instrument, the total scattered light,  $T_4$ , will be greater than the light scattered by the specimen by an amount proportional to  $T_3$  and equal to  $T_3$  times  $T_2/T_1$ . The corrected amount of light scattered by the specimen will then be:

$$T_4 - T_2 \left( \frac{T_2}{T_1} \right)$$

d) The diffuse luminous transmittance,  $T_4$ , is then calculated as follows:

$$T_d = \frac{T_4 - T_3 \frac{T_2}{T_1}}{T_1}$$

e) Percentage haze is then calculated from the ratio of diffuse,  $T_d$ , to total luminous transmittance,  $T_t$  as follows:

$$\begin{aligned} \text{Haze, percent} &= \frac{T_d}{T_t} \times 100 \\ &= \left[ \frac{T_4 - T_3 \left( \frac{T_2}{T_1} \right)}{T_1} + \frac{T_2}{T_1} \right] \times 100 \\ &= \frac{T_4 - T_3 \left( \frac{T_2}{T_1} \right)}{T_2} \times 100 \\ &= \left( \frac{T_4}{T_2} - \frac{T_3}{T_1} \right) \times 100 \end{aligned}$$

## A P P E N D I X J ( Clause 5.14 )

### TEST FOR RESIDUAL MONOMER IN SHEET

#### J-1. DETERMINATION OF RESIDUAL METHYLMETHACRYLATE

**J-1.1 Outlines of the Method** — Methylmethacrylate ( MMA ) content in polymethylmethacrylate ( PMMA ) is found out of gas-liquid chromatographic method. A solution of polymer in a suitable solvent is introduced into a gas liquid partition column and the components are separated as they pass through the column, with the carrier gas by different rates of adsorption on the column packing. The components are recorded on a chromatogram and calculated by comparing peak heights or areas with those obtained from a prepared standard analyzed under identical operating conditions, dilutions and volume of sample injected.

#### J-1.2 Apparatus

##### J-1.2.1 Chromatograph

a) *Detector* — A hydrogen flame detector of sufficient sensitivity.

- b) *Attenuator* — The instrument should be equipped with a multistep, attenuator to ensure maximum peaks from the detector output signal and keep within the recorder chart range.
- c) *Oven* — When operating isothermally oven should be capable of maintaining test temperature to an accuracy of  $\pm 0.3^\circ\text{C}$  during the time in which the test sample and corresponding reference standards are analyzed.
- d) *Gas Flow Regulators* — The metering mechanisms shall be capable of maintaining flow rates that are constant to  $\pm 0.5$  percent during the time in which the test sample and the corresponding reference standards are analyzed.
- e) *Recorder* — 0.1 millivolt with a full scale response time of one second.

**J-1.2.2 Column** — Any type or size of stainless steel column packed with suitable adsorbent which can ensure effective separation may be used. The recorder pen should return to the base line after tracing each peak.

**J-1.2.3 Microsyringe** — 10 microlitre capacity.

**J-1.2.4 Chemical balance** — Sensitivity 1 mg or better.

### **J-1.3 Reagents**

**J-1.3.1 Solvent** — The solvent shall be capable of completely dissolving the polymer, allowing column separation and of sufficient purity so as not to interfere in the analysis of the desired components. Acetone has been found satisfactory.

**J-1.3.2 Internal standard solvent to establish the calibration curve for methylmethacrylate monomer** select suitable internal standard solvent.

MIBK — have been found satisfactory.

**J-1.3.3 Carrier Gas** — Nitrogen or argon having sufficient purity.

**J-1.3.4 Hydrogen**

### **J-1.4 Procedure**

**J-1.4.1 Calibration** — Select the conditions of column temperature and carrier gas flow which shall produce adequate separation in the minimum amount of time and allow the instrument to come to equilibrium.

Accurately prepare reference standards and represent the high and low ends of the expected analytical range. The standards shall be dissolved in the solvent used for the analysis, and may be prepared as follows.

To establish the calibration curve for methylmethacrylate monomer in the expected range accurately weigh to the nearest 0.1 mg in the 100 ml volumetric flask approximately 2 mg of MMA for high reference standard and approximately 10 mg of MMA for high reference standard immediately after weighing dilute each flask with selected solvent to make equal volume and add equal known quantity of internal standard solvent into the respective flask place a serumstopper on each flask and mix thoroughly by shaking it for five minutes.

Introduce the desired quantity of standard into the instrument and allow the test sample to be completely eluted. Follow the same procedure for each prepared standard, being careful to introduce exactly the same volume, at room temperature each time. From standard chromatograms measure the peak heights of methylmethacrylate monomer and internal standard solvent used.

Calculate peak height of MMA/Peak height of internal standard solvent up to three decimal places. Prepare a calibration curve by plotting the above ratio on ordinate and the weight of methylmethacrylate ( mg ) on the abscissa. The calibration shall pass through zero and be the best fit to the other standard points.

**J-1.4.2 Procedure** — Weight approximately 0.15 g of polymers test sample to the nearest mg into 100 ml volumetric flask, dilute it with selected solvent, allow it to remain for 2 days for complete dissolution, add known quantity of internal standard solvent and with instrument set at the condition of reference standard, inject a test sample equal to volume at room temperature. After complete elution measure the peak heights of methylmethacrylate and internal standard solvent from the chromatogram obtained.

**J-1.5 Calculation** — Calculate the percent of residual methylmethacrylate in the polymer sample as follows:

- Calculate peak height of MMA/Internal standard peak height up to three decimal places ( B )
- Determine the weight of MMA ( A mg ) corresponding to ( B ) using a calibration curve prepared separately.

Residual methylmethacrylate percentage =

$$\begin{aligned} \frac{A \text{ ( mg )}}{1000} &\times \frac{100}{\text{sample ( g )}} \\ &= \frac{A \times 0.1}{\text{sample ( g )}} \end{aligned}$$

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